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A 500-year record of summer cloud cover from stable carbon isotopes in Norwegian tree-rings

G.H.F. Young (1), D. McCarroll (1), N.J. Loader (1), and A.J. Kirchhefer (2)

(1) School of the Environment and Society, Swansea University, Singleton Park, Swansea, SA2 8PP (g.h.f.young@swansea.ac.uk), (2) Department of Biology, University of Tromsø, N-9037, Tromsø, Norway

Tree-ring stable carbon isotope ratios (δ^{13}C) in moist environments are likely to be driven by photosynthetic rate, and thus sunshine, rather than temperature, should represent the most direct controlling factor. Due, often, to the lack of availability of long instrumental records of sunshine δ^{13}C have, however, typically been calibrated with and, therefore, used to reconstruct growing season temperatures. This, often necessary, but imperfect, interpretation relies on the assumption that temperature and sunshine co-vary. This is tested using a δ^{13}C series from Scots pine trees (*Pinus sylvestris* L.) in NW Norway, where long (>100 yr) records of both summer temperature and cloud cover are available. It is demonstrated that when summer temperature and δ^{13}C diverge, summer temperature and cloud cover also diverge, suggesting that cloud cover, and not temperature, provides the stronger and more consistent parameter with which to calibrate tree-ring δ^{13}C series in this area. When a 500-year reconstruction of summer cloudiness is compared with a published reconstruction of summer temperatures, based on tree-ring maximum densities, in northern Sweden, the two series largely agree with high levels of annual-decadal coherence. There are, however, three distinct periods of lower frequency divergence; two (AD 1600-1650 and AD 1900-1927) when it appears likely that summers were cool but sunny, and one during the first half of the 16^{th} century when summers were warm but cloudy. These periods where the covariance between temperature and sunshine are uncoupled may represent large scale changes in circulation as recorded in the Arctic Oscillation (AO) index. Strongly negative values of the summer AO index, as in the early 20^{th} century, are associated with persistent high pressure over northern Norway and Fennoscandia, bringing cool summers with clear skies. Long reconstructions of cloudiness from tree-ring δ^{13}C series at suitable locations, may prove extremely valuable for testing General Circulation Models (GCMs), as the generation of cloud is a strong control on temperature evolution, but remains one of the greatest sources of uncertainty.